Egyptian Journal of Forensic Sciences (2011) 1, 103–108

Forensic Medicine Authority

Egyptian Journal of Forensic Sciences

www.sciencedirect.com

ORIGINAL ARTICLE

Stature estimation using anthropometric measurements from computed tomography of metacarpal bones among Egyptian population

Jaklin Fekri Zaher *, Nadia Farouk Mohamed El-Ameen, Amany Edward Seedhom

Faculty of Medicine, Minia University, Minia, Egypt

Available online 31 May 2011

KEYWORDS

Forensic anthropology;
Stature estimation;
Second and third metacarpals' dimensions;
MDCT;
Egyptians

Abstract Identification of an individual is the mainstay in forensic investigation. Estimation of stature plays a significant role in establishing personal identity. A sample of 157 Egyptian subjects {82 males and 75 females} ranging from 21 to 40 years was taken. Their statures were determined. Then, multi-detector computed tomography (MDCT) was done for their left hands to measure length and width of second and third metacarpal bones. Statistical analysis revealed that sex differences were found to be significant for all parameters ($P \leqslant 0.05$) by Student's *t*-test. Pearson's correlation was found to be statistically significant between stature and all variables for females and between stature and second metacarpal width and third metacarpal length and width for males. Linear regression equations were calculated with a standard error of estimate (SEE) ranged from ± 4.53 cm to ± 4.71 cm for males and from ± 5.45 cm to ± 5.87 cm for females. Multiple (stepwise) regression equations were also calculated resulting into one model for males and two models for females with the SEE ± 4.5 cm for males and ± 5.22 cm and 5.45 cm for females. Consequently, it was concluded that stature can be determined successfully using second and third metacarpals' dimensions among Egyptians.

1. Introduction

With the increasing frequency of mass disasters and fatal assaults, the identification of isolated extremities and their parts is the ultimate goal in the investigation for identity of victims.[1]

Forensic anthropologists work on skeletal remains recovered from a scene of crime to extract relevant informations about the victim.[2]

The process generally begins with formulation of a biological profile (osteo-biography); specifically, estimation of sex, age, ethnicity and stature.[3]

Forensic anthropologists while dealing with skeletal remains have very little choice to use anatomical method for

* Corresponding author.
E-mail address: jacky7009@hotmail.com (J.F. Zaher).

Peer review under responsibility of Forensic Medicine Authority.
doi:10.1016/j.ejfs.2011.03.002

ELSEVIER Production and hosting by Elsevier

stature reconstruction due to non-availability of complete skeleton from a scene of crime in most of the cases. Thus, they have no choice to use a relatively less precise method of stature reconstruction, i.e. the mathematical method. It is the method for calculating the height by considering the mathematical regression coefficients obtained from the measurements of many bones of the body.[4]

A formula for one population does not necessarily yield reliable results for another due to inherent population variations that may be attributed to genetic and environmental factors as climate, nutrition and lifestyle. Thus, separate regression formulae should be developed in order to determine stature for each population group.[5]

Computed tomography (CT) is a technique that can be used to obtain true dimensions of bones by moving orthogonal beam of X-rays along the length of the structure being measured.[6]

There is a scarcity of literature regarding the estimation of stature (height) from metacarpal bones' dimensions among Egyptian population and stature formulae are population specific. Therefore, the aim of the present study was to set general formulae of stature estimation for both males and females using anthropometrical measurements of second and third metacarpal bones by multi-detector computed tomography (MDCT) in some Egyptian adults.

2. Subjects and methods

This study included 157 adult Egyptian volunteers (82 males and 75 females) recruited in the period from August 2010 to January 2011. Their ages ranged between 21 and 40 years. The lower age limit was 21 years to be sure of completion of skeletal development and attaining maximum growth and maximum length of different body parts. Some of them were students in the Faculty of Medicine, Minia University while others were workers in the University Hospital who had no somatic diseases and without any signs of a disease or trauma.

Exclusion criteria were put: skeletal immaturity, history of fractures, bone tumors or arthritis, pathological lesions such as congenital and developmental dysplasia, metabolic bone diseases, connective tissue diseases and previous orthopedic surgery were excluded from this study to ensure normal bone evaluation. Also, left handed subjects were excluded.

According to standard ethics of Minia University ethical committee for human experimentation, informed consents were obtained from every one of them. They were asked to fill a preliminary questionnaire about demographic characteristics like age, socioeconomic status, place of birth, place of residence and occupation.

Stature (*S*) was measured in standing posture with the subject barefooted and without a hat on his head. Subjects were instructed to stand with both feet in close contact to each other; head was oriented such that the Frankfurt plane (the lateral palpebral commissure and the upper border of the external auditory meatus) was in a horizontal plane parallel to the feet according to Krishan and Sharma.[7] Stature was obtained in centimeters as the distance between the standing surface and the highest point on the head (vertex) determined by the movable rod of anthropometer in the midsagittal plane. Then, they were referred to Radiology Department at the University Hospital for multi-detector computed tomography (MDCT) examination of their left hands.

2.1. MDCT protocol for image acquisition

The CT studies were performed using 16-detector CT scanner (Bright Speed 16; GE Medical Systems). Scanning along the axial axis of the entire left hand starting from the lower end of both radius and ulna, including the carpal joint through the metacarpals and phalanges was performed using the following parameters: 120 kVp, 260 mAs, a helical pitch of 0.562:1, 0.8 s scan time, 16×1.25 mm detector configuration, 8.8 s total exposure time, 1.25 mm helical slice thickness, and 0.6 mm reconstruction interval with a small field of view (FOV). Images were reconstructed using bone algorithm.

2.2. Reconstruction and post-processing considerations

Axial source images were transferred to an Advantage Workstation (AW) Volume Share 2 (GE Healthcare) where multiplanar reformatted (MPR) and three-dimensional (3D) image reconstruction were done.

Multi-planar reformatted (MPR) images were obtained in coronal plan through the entire left hand. The lengths of the second (2nd) and third (3rd) metacarpal bones were measured from the midpoint of the bases to the distal tip point of the bone using a measuring distance tool which is the software in the MDCT machine. Widths of the 2nd and 3rd metacarpal bones were measured as the perpendicular distance to the line passing through the midpoint of the line passing through the two foremost points of the metacarpals. Coronal MPR allowed accurate anatomical delineation of the hand bones with their fine details; subsequent more accurate measurements in millimeters than that of plain X-ray were appreciated.

Three-dimensional (3D) reconstruction image of the entire left hand was performed using the volume viewer 3.1 which is powerful 3D software. It enables a 3D image simulating that of the original bony skeleton of the hand.

Statistical evaluation was performed using SPSS version 11.0. Student's *t*-test was calculated to detect sex differences for all variables. Pearson's correlation and regression analysis were used to determine the relationship between the variables and to obtain the unknown variable using the known one (i.e. reconstruction of stature). Regression equations (Linear and Multiple) for both males and females with their corresponding determination coefficients (R^2) and standard error of estimates (SEE) were also obtained.

3. Results

The descriptive statistics for age (year), stature (cm), dimensions (mm) of second and third metacarpals for both males and females are shown in Table 1. Minimum, maximum, mean, standard deviation and standard error of mean for different variables were listed. The mean values of all measurements were higher in case of males than females. Table 2 lists the sex differences in all variables which were statistically significant ($P \leqslant 0.05$) by Student's *t*-test.

Table 3 illustrates the correlation coefficients between stature and length and width of second and third metacarpals in both sexes. All variables showed statistically significant correlation coefficients with stature ($P \leqslant 0.05$) in females ($r = 0.16$, 0.17, 0.40, 0.34 for second and third metacarpals lengths and second and third metacarpals widths, respectively) but in males

Table 1 Descriptive statistics for different variables in both sexes.

Variable	Sex	Number	Minimum	Maximum	Mean	S.D.	S.E.M.
Age	Male	82	21	40	28.07	5.61	0.62
	Female	75	21	40	26.13	5.31	0.61
Stature	Male	82	156	179	170.04	4.69	0.52
	Female	75	155	180	165.76	5.89	0.68
Length[a]	Male	82	57	76	67.37	4.55	0.50
	Female	75	52	78	63.75	6.01	0.69
Length[b]	Male	82	54	76	66.26	4.13	0.46
	Female	75	52	77	62.15	5.62	0.65
Width[a]	Male	82	7.0	11.0	9.09	0.98	0.11
	Female	75	6.7	11.0	8.18	1.16	0.13
Width[b]	Male	82	6.9	11.0	9.17	1.10	0.12
	Female	75	6.2	10.0	8.08	1.09	0.13

S.D.: standard deviation; S.E.M.: standard error of mean.
[a] Second metacarpal.
[b] Third metacarpal.

Table 2 Comparison of different variables between males and females.

Variable	Sex	Number	Mean	S.D.	*t*-Test	*P*-value
Age	Male	82	28.07	5.61	2.2	0.02*
	Female	75	26.13	5.31		
Stature	Male	82	170.04	4.69	5.05	0.0001**
	Female	75	165.76	5.89		
Length[a]	Male	82	67.37	4.55	4.27	0.0001**
	Female	75	63.75	6.01		
Length[b]	Male	82	66.26	4.13	5.25	0.0001**
	Female	75	62.15	5.62		
Width[a]	Male	82	9.09	0.98	5.30	0.0001**
	Female	75	8.18	1.16		
Width[b]	Male	82	9.17	1.1	6.24	0.0001**
	Female	75	8.08	1.09		

S.D.: standard deviation.
[a] Second metacarpal.
[b] Third metacarpal.
* Significant.
** Highly significant.

second metacarpal width and third metacarpal length and width measurements showed statistically significant correlation coefficients with stature ($P \leqslant 0.05$) {$r = 0.18$, 0.19 and 0.28 for second metacarpal width and third metacarpals length and width, respectively}. Correlation coefficients of width measurements were higher with the highest correlation coefficient which was exhibited by second metacarpal width ($r = 0.4$) in females. While in males, third metacarpal width had the highest correlation coefficient ($r = 0.28$).

The linear regression equations for estimation of stature from all variables in both sexes are presented in Table 4. Regression equations have been computed separately for each sex and each variable. The table also exhibits standard error of estimate (SEE) and determination coefficient (R^2).

The standard error of estimate (SEE) predicts the deviation of estimated stature from the actual stature. A low value indicates greater reliability in the estimated stature. It ranged between ± 4.53 cm and ± 4.71 cm for males and between ± 5.45 cm and ± 5.87 cm for females, i.e. it ranged from ± 4.53 cm to ± 5.87 cm generally.

Table 5 lists the multiple (stepwise) regression equations for estimation of stature (cm) from different variables. One model was achieved for males (SEE = ± 4.5 cm and $R^2 = 0.1$) and two models for females (SEE = ± 5.22 cm and ± 5.45 cm, respectively, and $R^2 = 0.16$ and 0.23). It was observed that the multiple regression equations revealed lower values of SEE and higher values of determination coefficients (R^2) compared to the values given by linear regression equations.

Table 3 Correlation between stature and different measurements.

Variable	Correlation	Males (82)	Females (75)
Length[a]	Value of (*r*)	0.10	0.16
	P-value	0.50	0.05*
Length[b]	Value of (*r*)	0.18	0.17
	P-value	0.05*	0.05*
Width[a]	Value of (*r*)	0.19	0.4
	P-value	0.05*	0.0001**
Width[b]	Value of (*r*)	0.28	0.34
	P-value	0.01*	0.001**

(*r*): correlation; *P*: significance.
[a] Second metacarpal.
[b] Third metacarpal.
[*] Significant.
[**] Highly significant.

Interpretations suggest that multiple regression equations are better indicators of stature estimation. Moreover, the multiple (stepwise) regression equation using second metacarpal width and third metacarpal length in females was better than the equation using second metacarpal width due to its smaller SEE (±5.22 compared to ±5.45) and higher R^2 (0.23 compared to 0.16).

4. Discussion

Estimation of stature is one of the important initial steps during forensic analysis of human skeletal remains and a major challenge in every country.[8] However, limb length to stature proportions differ between human populations.[9]

Studies have shown that stature can be estimated from length of long bones, bone fragments, spine, hand and foot dimensions, metacarpal and metatarsal lengths, scapula, and skull.[10] It is essential for stature estimation to use not only equations based on forensic statures, but also equations based on modern samples.[11] Owing to the paucity of literatures concerning this point in Egyptians, the aim of this study was to develop general regression models for stature estimation using true dimensions (length and width) of second and third metacarpal bones measured by multi-detector computed tomography (MDCT) of 157 adult Egyptian males and females.

The Egyptian perspectives of the problem of stature estimation have been studied by Abdel-Malek et al.,[12] who studied prediction of stature from hand length and breadth in 166 University students, El-Meligy et al.,[13] who used percutaneous tibial length and bimalleolar breadth for estimation of body built in 1000 individuals, and Habib and Kamal,[14] who estimated stature from lengths of hands and phalanges of 159 persons.

Many studies have been carried out to estimate stature by taking measurements from radiographic materials.[15,16] There are different methods in obtaining metacarpal measurements, generally categorized into invasive and non-invasive. CT is a precise, non-invasive, practical and more accessible mode of measurement, and delivers the minimum radiation dose to subjects.[17] It is a highly accurate method to determine bone length with a radiation dose of 3–6 times less than the conventional technique.[18] Therefore, it was a suitable tool for metacarpal measurement in this study.

Effect of hand dominance has been suggested.[19] Therefore, left hand was selected in this study. In contrast to that finding, Lazenby,[20] found no dominant effects due to hand sidedness although it has been reported that right metacarpal geometric parameters being larger than those observed on the left hand. Row and Cavanagh,[21] reported that stature estimation may be attempted only after attainment of maturity. Thus, participants in this study were 21–40 years old.

The current study revealed that there was a statistically significant difference between males and females as regards the

Table 4 Linear regression equations for estimation of stature (cm) from different measurements in both sexes.

Males (82)			Females (75)		
Regression equations	±SEE	R^2	Regression equations	±SEE	R^2
$S = 174.99 - 0.074 \times \text{length}^a$	±4.71	0.01	$S = 156.06 + 0.15 \times \text{length}^a$	±5.87	0.02
$S = 183.65 - 0.205 \times \text{length}^b$	±4.64	0.03	$S = 154.6 + 0.18 \times \text{length}^b$	±5.85	0.03
$S = 175.079 - 0.56 \times \text{width}^a$	±4.69	0.01	$S = 182.32 - 2.02 \times \text{width}^a$	±5.45	0.20
$S = 181.13 - 1.21 \times \text{width}^a$	±4.53	0.01	$S = 180.43 - 1.82 \times \text{width}^b$	±5.59	0.11

SEE: standard error of estimate; R^2: determination coefficient; *S*: stature.
[a] Second metacarpal.
[b] Third metacarpal.

Table 5 Multiple (stepwise) regression equations for estimation of stature (cm) from different measurements in both sexes.

Males (82)			Females (75)		
Regression equations	±SEE	R^2	Regression equations	±SEE	R^2
$S = 181.13 - 1.2 \times \text{width}^a$	±4.5	0.1	$S = 182.32 - 2.02 \times \text{width}^b$	±5.45	0.16
			$S = 166.46 - 2.4 \times \text{width}^b + 0.3 \times \text{length}^a$	±5.22	0.23

S: stature; SEE: standard error of estimate; R^2: determination coefficient.
[a] Third metacarpal.
[b] Second metacarpal.

dimensions of the studied bones. This was in agreement with previous observations made by others,[7,12–14,22] who found higher mean values in all anthropometric measurements in males compared to females. They attributed that result to the early maturity of females than males; consequently, males have two more years of physical growth.

The present results showed that stature is correlated significantly with all variables in females (statistically significant) and with third metacarpal length and second and third metacarpal width dimensions in males. This was consistent with previous results undertaken by others on hand length.[12,14] However, previous studies on other populations had found stronger correlation between stature and metacarpal lengths. In the findings reported by Meadows and Jantz,[23] the correlation of stature with metacarpal lengths ranged from 0.565 to 0.828 in American white and black adults. They reported that the metacarpal relationship with stature was shown to be stronger than those for long bone fragments. Odita et al.[24] also established correlation coefficient ranging from 0.93 to 0.95 for metacarpals in Nigerian children. Onat's study[25] had shown that metacarpal length has the closest correlation with stature followed by metacarpal diameter and cortical thickness in 110 Turkish girls. Wilbur[26] had estimated femur length from second and third metacarpal lengths and subsequently used that estimate in stature estimation. Karaman et al.[4] revealed strong significant correlations for Turkish population between stature and second metacarpal length ($r = 0.785$) and third metacarpal length ($r = 0.743$).

Linear regression models are derived to reconstruct stature when a single dimension from the extremities is available.[1] The reliability of stature estimation using regression equations is revealed by standard error of estimate (SEE) which predicts the deviation of estimated stature from actual stature and is considered a measure for accuracy of the equations.[27] In the present study, four models for both sexes with a low SEE (range from ± 4.53 cm to ± 4.71 cm for males and from ± 5.45 to ± 5.87 cm for females) were obtained upon using linear regression equations. Actually, SEE recorded in this study was lower than that recorded previously (for Egyptians from other dimensions) by Abdel-Malek et al.,[12] who determined SEE as ± 5 cm for hand length and El-Meligy et al.,[13] who reported a SEE from ± 6.51 cm to ± 8.24 cm upon using tibial length for reconstruction of stature. Also, it was smaller than that achieved by Habib and Kamal,[14] who set models for stature estimation in Egyptians using lengths of hands and phalanges with a SEE range from ± 5.3 cm to ± 7.27 cm.

SEE of the present study can be compared with similar studies of different populations as Meadows and Jantz study,[23] who obtained a SEE of ± 5.1 to ± 8.14 cm for metacarpals in Americans and ± 6.92 cm in the study of Kimura on Japanese.[28] SEE of this study was also smaller than both of them.

In the present study, multiple (stepwise) regression equations in both males and females (one model for males and two models for females) were more reliable than equations obtained from single variable (linear) as they resulted into lower SEE (± 4.5 cm for males and ± 5.22 cm to ± 5.45 cm for females). This was in agreement with Karaman et al.[4] who set five stepwise models for second and third metacarpals with the SEE ranged from ± 0.87 cm to ± 5.54 cm. However, Habib and Kamal[14] set one model for males (SEE = ± 5.3 cm) and three for females (SEE = ranged from ± 4.22 cm to ± 4.54 cm) using lengths of hands and phalanges in Egyptians. These findings coincided with Ozden et al.,[29] who achieved a smaller SEE in multiple regression equations for 569 Turkish individuals and concluded that multiple regression equations are better indicators of stature. Similarly, Dayal et al.[30] revealed a higher accuracy in stature estimation when using more than one dimension in South Africans Whites. Lastly, Rastogi et al.[31] reported that multiple regression equations gave better results for North and South Indians.

Consequently, it was concluded that accurate determination of length and width of second and third metacarpal bones by computed tomography may be a simple, reliable and practical method for stature estimation of Egyptian adults in forensic practice. This may be helpful to obtain approximate stature when there is difficulty in obtaining a direct measurement as in amputated hand or arm, mutilated bodies, accidents, mass disasters, severely decomposed bodies and skeletal remains.

5. Recommendations

- Dimensions of second and third metacarpal bones can be used successfully for estimation of stature in forensic practice by law enforcement agencies and forensic scientists.
- Multiple regression equations are better than linear equations and must be preferred when possible.
- Further researches for Egyptians must be done using larger number of subjects.
- Further researches for other populations using CT for metacarpal bones are recommended.

References

1. Kanchan J, Krishan K, Sharma A, Menezes RG. A study of correlation of hand and foot dimensions for personal identification in mass disasters. *Forensic Sci Int* 2010;**199**(1–3), 112.e1–6.
2. Krishan K. Estimation of stature from footprint and foot outline dimensions in Gujjars of North India. *Forensic Sci Int* 2008;**175**(2–3):93–101.
3. Franklin D. Forensic age estimation in human skeletal remains: current concepts and future directions. *Leg Med* 2010;**12**(1):1–7.
4. Karaman AG, Teke HY, Gunay I, Doğan B, Bilge Y. Height estimation using anthropometric measurements on X-rays of wrist and metacarpal bones. *Internet J Biol Anthropol* 2008;**2**(1), ISSN: 1939-4594.
5. De-Mendonça MC. Estimation of height from the length of long bones in a Portuguese adult population. *Am J Phys Anthropol* 2000;**112**:39–48.
6. Fan T, Chen XG, Xhou XR, Zhang ZH, Deng ZH, Wang HX. Stature estimation from length of tibias and fibulas measured on computed radiography of living body. *Fa Yi Xue Za Zhi* 2008;**24**(2):118–21.
7. Krishan K, Sharma A. Estimation of stature from dimensions of hands and feet in a North Indian population. *J Forensic Leg Med* 2007;**14**(6):327–32.
8. Menezes RG, Kanchan T, Kumar GP, Jagadish PP, Lobo SW, Uysal S, et al. Stature estimation from the sternum in South Indian males. *J Forensic Leg Med* 2009;**16**(8):441–3.
9. Raxter MH, Ruff CB, Azab A, Erfan M, Soliman M, El-Sawaf A. Stature estimation in Ancient Egyptians: a new technique based on anatomical reconstruction of stature. *Am J Phys Anthropol* 2008;**136**(2):147–55.

10. Jagadish PP, Sowmya J, Yoganarasimha K, Ritesh G, Kanchan R, Aswinidutt R. Estimation of stature from cranial sutures in a South Indian male population. *Int J Legal Med* 2009;**123**:271–6.
11. Wilson RJ, Herrmann NP, Jantz LM. Evaluation of stature estimation from the database for forensic anthropology. *J Forensic Sci* 2010;**5**(3):684–9.
12. Abdel-Malek AK, Ahmed AM, Sharkawi SA, Hamid NM. Prediction of stature from hand measurements. *Forensic Sci Int* 1990;**46**:181–7.
13. El-Meligy MM, Abdel-Hady RH, Abdel-Maaboud RM, Mohamed ZT. Estimation of human body built in Egyptians. *Forensic Sci Int* 2006;**159**(1):27–31.
14. Habib SR, Kamal NN. Stature estimation from hand and phalanges lengths of Egyptians. *J Forensic Leg Med* 2010;**17**:156–60.
15. Munoz JI, Iglesias M, Penaranda JM, Mayo M, Mignuens M. Stature estimation from radiographically determined long bone length in a Spanish population sample. *J Forensic Sci* 2001;**46**(2):363–6.
16. Warren MW, Smith KR, Stulblefield PR, Martin SS, Walsh-Haney HM. Use of radiographic atlases in a mass fatality. *J Forensic Sci* 2000;**45**(2):467–70.
17. Berthold LD, Ishaque N, Nauermann F, Klose KJ, Peter A. Measurement of torsion angles of long finger bones using computed tomography. *Skeletal Radiol* 2001;**30**:379–83.
18. Aaron A, Weinstein D, Thickman D, Eilert R. Comparison of ortho-entgenography and computed tomography in the measurement of limb length discrepancy. *J Bone Joint Surg Am* 1992;**74**(6):897–902.
19. Sushil K, Srivastava AK, Sahai MB. Estimation of stature by anthropometric examination of forearm and hand. *J Indian Acad Forensic Med* 2010;**32**(1):62–5.
20. Lazenby RA. Circumferential variation in human second metacarpal cortical thickness: sex, age and mechanical factors. *Anat Rec* 2002;**267**:154–8.
21. Row PS, Cavanagh PR. Estimation of stature from footprints. *Clin Biomech* 2007;**22**(2):155–64.
22. Kumar A, Purwar B, Kreshna G, Agnihotri A, Jeebun J. Estimation of stature by foot length. *J Forensic Leg Med* 2007;**14**(5):279–83.
23. Meadows L, Jantz RL. Estimation of stature from metacarpal lengths. *J Forensic Sci* 1992;**37**(1):147–54.
24. Odita JC, Okolo AA, Ukoli F. Normal values for metacarpal and phalangeal lengths in Nigerian children. *Skeletal Radiol* 1991;**20**:441–5.
25. Onat T. Growth of metacarpal during female adolescence: relationship to stature, weight and skeletal and sexual maturity. *Am J Hum Biol* 1997;**9**:425–38.
26. Wilbur AK. The utility of hand and foot bones for the determination of sex and the estimation of stature in a prehistoric population from West-Central Illinois. *Int J Osteoarchaeol* 1998;**8**:180–91.
27. Bidmos M. Adult stature reconstruction from the calcaneous of South Africans of European descent. *J Clin Forensic Med* 2006;**13**(5):247–52.
28. Kimura K. Estimation of stature from second metacarpal length in Japanese children. *Ann Hum Biol* 1992;**19**(3):267–75.
29. Ozden H, Balci Y, Canan D, Akin T. Stature and sex estimate using foot and shoe dimensions. *Forensic Sci Int* 2005;**147**(2–3):181–4.
30. Dayal MR, Steyn M, Kevin L, Kuykendall L. Stature estimation from bones of South Africans whites. *S Afr J Sci* 2008;**104**:124–8.
31. Rastogi P, Nagesh KR, Yoganaraimha K. Estimation of stature from hand dimensions of North and South Indians. *Leg Med* 2008;**10**(4):185–9.